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Water Usage Characteristics of Household Appliances and the Potential for Water Savings

Robert L. Palla

Center for Consumer Product Technology
National Engineering Laboratory
U.S. Department of Commerce
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Prepared for:
Office of Policy Development and Research
Department of Housing and Urban Development
Washington, DC 20410

U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

PREFACE

This report is one of a group documenting National Bureau of Standards (NBS) research and analysis efforts in developing water conservation test methods, models for technical and economic analysis, and strategies for implementation and acceptance of practices. This work is sponsored by the Department of Housing and Urban Development, Office of Policy Development and Research, Energy, Building Technology and Standards Division, under Interagency Agreement H-48-78.

ABSTRACT

A study has been undertaken to quantify appliance water consumption and the effectiveness of various consumer usage techniques and manufacturer design modifications for saving water. Appliances considered are clothes washers and dishwashers. Through a comparison of estimated water savings, the study indicates that the most significant means of saving water are those which are already commercially available -- front-loading machines and suds-saver options for clothes washers, and short-cycle settings for dishwashers. Water savings of about 20 to 30 percent are estimated with these features, or about 10 gallons for clothes washers and 3 gallons for dishwashers.

Several appliance design modifications are also evaluated but do not offer the same level of savings. Water usage characteristics such as supply and discharge flow rates and the effect of supply pressure and cycle selection are presented.

Table of Contents

		Page
	Preface	i
	Abstract	ii
	List of Tables	v
	List of Figures	v
1.	Introduction	1
2.	Laboratory Test Appliances	1
3.	Appliance Water Consumption, and Supply/ Discharge Characteristics	2
	3.1 Clothes Washers	2
	3.1.1 Water Consumption	2
	3.1.2 Supply and Discharge Characteristics	3
	3.2 Dishwashers	3
	3.2.1 Water Consumption	3
	3.2.2 Supply and Discharge Characteristics	4
4.	Effects of Various Parameters on Water Consumption	4
	4.1 Clothes Washers	4
	4.1.1. Load Size/Water Level Setting	4
	4.1.2 Cycle Selection	4
	4.1.3 Supply Pressure	5
	4.1.4 Temperature Selection	5
	4.2 Dishwashers	5
	4.2.1 Cycle Selection	5
	4.2.2 Supply Pressure	6

Page

5. Options and Design Modifications for Appliance Water Conservation 7

5.1 Water Conservation Options for Clothes Washers. . . 7

5.1.1 Front-Loading Machines 7

5.1.2 Suds-Saver Devices 7

5.1.3 Better Use of Existing Water Levels Controls 8

5.2 Water Conservation Design Modifications for Clothes Washers 8

5.2.1 Reduce Tub Volume. 8

5.2.2 Reduce Clearance Between Inner and Outer Tubs 9

5.2.3 Develop Automatic Water Level Control. . . . 9

5.3 Water Conservation Options and Design Modifications for Dishwashers 9

5.3.1 Reduce the Number of Water Changes 9

5.3.2 Reduce the Quantity of Water Used Per Water Change 10

6. Summary and Conclusions. 10

7. References 12

List of Tables

Table 1 - Typical Wash/Rinse Phasing for Clothes Washers

Table 2 - Clothes Washer Water Consumption Breakdown for Various Fill Levels

Table 3 - Some Reported Values for Clothes Washer Water Consumption

Table 4 - Clothes Washer Supply and Discharge Flow Rates

Table 5 - Dishwasher Cycle Phasing, Water Consumption, and Washing Index

Table 6 - Manufacturers' Estimates of Dishwasher Water Consumption at Various Cycle Settings

Table 7 - Dishwasher Supply and Discharge Flow Rates

Table 8 - Typical Weights of Clothes Loads Washed

Table 9 - Increase in Clothes Washer Tub Volume in Recent Years

Table 10 - Water Savings Attainable at Maximum Fill Levels by Reducing Inner-to-Outer Tub Clearance to 0.5 Inches

Table 11 - Water Conservation Design Options and Estimated Water Savings for Clothes Washers

Table 12 - Water Conservation Design Options and Estimated Water Savings for Dishwashers

List of Figures

Figure 1 - Schematic of a Typical Top-Loading Clothes Washer

Figure 2 - Distribution of Static Water Pressure Found in a Survey of Residences Throughout the United States

Figure 3 - Effect of Water Supply Pressure on Dishwasher Water Consumption

1. INTRODUCTION

Water-consuming appliances, namely clothes washers and dishwashers, account for approximately 20 percent of all water used within a typical household [1].* As residential water usage accounts for roughly 40 percent of all potable fresh water consumption (excluding irrigation) [1], the contribution of appliances to total national water use is appreciable. In addition, and perhaps even more significant, is the energy used to heat this water. Water heating accounts for 14 percent of residential energy consumption [2]. Appliances use about one-third of all hot water--an amount equivalent to 1 percent of national energy use. Also, the demands appliances place on residential water supply and drainage systems, for example, high discharge rates, may preclude water conservation efforts involving the down-sizing of plumbing components.

As we approach an era in which wiser use of our resources is a necessity, an examination of appliance water usage characteristics and the potential for water savings is in order. Such an examination was conducted by the Center for Consumer Product Technology (CCPT) at the National Bureau of Standards (NBS). This study was part of a comprehensive water conservation program sponsored by the Department of Housing and Urban Development (HUD) through the Center for Building Technology (CBT). The three primary objectives for the CCPT study were to:

- o determine typical clothes washer and dishwasher water consumption, and supply/discharge characteristics,
- o assess the effects of various parameters, such as cycle selection and water pressure, on water consumption, and
- o evaluate techniques for appliance water conservation and estimate the corresponding water and energy savings potential.

The purpose of this study was to identify appliance parameters, usage techniques, and options available to manufacturers and consumers, which offer the most substantial water savings. Information and data developed through this effort was to serve as an input to other portions of the CBT program, and as a basis for HUD consumer information publications and HUD policy regarding minimum performance standards for rehabilitative housing.

Results of the study indicate that substantial water savings are attainable through several means, involving altering consumer habits and modifying appliance design. By changing consumer habits alone, appliance water usage can be reduced by about one third. This corresponds to a 7 percent reduction in residential water usage. However, water savings are not always obtained without trade-offs since reductions in water consumption may affect appliance performance. As performance encompasses many often subjective factors, such as "gentleness of action" and "tangle free action" for clothes washers, the effect of water conservation on performance has not been evaluated here. Rather, it is felt that performance would best be dealt with by appliance manufacturers, with performance and water conservation features being traded off in the normal workings of the marketplace.

*Numbers in brackets refer to references on page 12.

2. LABORATORY TEST APPLIANCES

The evaluation of effects of various parameters on appliance water usage characteristics was based on NBS laboratory testing and on existing studies. Five different model clothes washers and seven different model dishwashers were selected for laboratory tests. These units were purchased between 1975 and 1976 for use in the appliance energy efficiency program within CCPT. Because no significant changes in appliance water consumption have occurred over the past few years in the industry [3], these units remain representative of currently available models in this respect. Throughout this report, values for parameters such as water consumption and supply flow rate are presented for test units as well as other model appliances. When the values presented are based on NBS laboratory tests, the appliance model is referred to as a "test unit" and is denoted by the symbol CW or DW for clothes washers and dishwashers, respectively.

3. APPLIANCE WATER CONSUMPTION AND SUPPLY/DISCHARGE CHARACTERISTICS

3.1 Clothes Washers

The purpose of a clothes washer is to remove soil from garments and fabrics. Various wash cycles are available for performing this function. A typical wash cycle, usually termed the "normal" cycle, consists of a wash, spray rinse, and deep rinse, sometimes followed by another spray rinse. (These parts of a complete cycle are referred to as subcycles in this report). In contrast, the "permanent press" cycle generally consists of a wash followed by several partial rinses and a deep rinse. Typical wash/rinse phasing for the "normal," "permanent press," and "soak" cycle settings is shown in Table 1. It should be pointed out, however, that phasing and water consumption on these as well as other wash cycles may vary among clothes washer models. Several other wash cycles such as "heavy-soil" and "knits" are also available on many machines. These cycles differ in the number and order of washes and rinses, and in some cases, agitation speeds.

3.1.1 Water Consumption

The wash and deep rinse subcycles of conventional large-capacity, top-loading machines use about 23 gallons of water each at the maximum fill level settings, and and 12 gallons each at the minimum fill level setting. (Most machines are equipped with a variable water level control which permits this adjustment). The spray rinse subcycle uses three to five gallons, bringing the water consumption for a complete normal cycle to about 50 gallons at the maximum fill level setting. A breakdown of water consumption for several test units is presented in Table 2. Additional estimates of total water consumption obtained from the literature are presented in Table 3 for various manufacturers models.

The temperature of the water used in the wash and deep rinse subcycles (hot, warm, or cold) may be selected independently, but the spray rinse temperature cannot. It is usually dependent on wash and deep rinse temperature selection and may vary from one machine to the next, for example, a warm wash/cold rinse temperature selection might give a warm spray rinse on one machine but a cold spray rinse on another.

3.1.2 Supply and Discharge Characteristics

While the volume of water consumed by appliances is of primary interest here, the rate at which it is supplied to and discharged from appliances can ultimately determine the feasibility of other water conservation options involving the downsizing of residential supply and drainage piping systems. The supply and discharge flow rates for several model clothes washers were therefore measured as part of this study.

Supply and discharge flow rates for five machines tested are presented in Table 4. At a given pressure, these rates are essentially constant due to the fixed orifice in the fill valve and constant discharge pump capacity. It can be observed from the data presented that both supply and discharge flow rates differ substantially between machines. Supply flow rates ranged from a low of about 4 gallons per minute to a high of about 9 gallons per minute. Discharge flow rates ranged from about 9 gallons per minute to 16 gallons per minute.

3.2 Dishwashers

The automatic dishwasher is a kitchen appliance for washing food preparation utensils and dining dishes and flatware. Several dishwashing cycles are generally available for performing this function. Most common are the "normal," "rinse-hold", and "short wash" cycles, but "super wash," "energy saver," and other special cycles are also available on many machines. All of these cycles use only hot water.

Dishwasher operation and water consumption are dependent on the wash cycle selected. The "normal" cycle typically consists of a wash, a rinse, a second wash, and two or three rinses, with water changes occurring between each of these subcycles. The phasing and number of wash and rinse cycles is not uniform among dishwashers though, even on the "normal" cycle. As data presented in Table 5 indicates, the phasing as well as water consumption and washing performance differs substantially.

The "short wash" cycle, useful for lightly soiled dishes requiring less washing action, is essentially the same as the "normal" cycle with the first wash and first rinse eliminated.

3.2.1 Water Consumption

The volume of water consumed in each water change of the dishwashing cycle is usally two to three gallons, with the water consumption for the entire normal wash cycle (all hot water) being between 13 and 15 gallons. Water fills are timed, however, making water consumption somewhat pressure-dependent. (Pressure effects are discussed later in Section 4.2.2). Measured values of total water consumption are presented in Table 5 for several dishwashers on the normal cycle. Some manufacturers' estimates of water consumption on this and various other cycle settings are presented in Table 6 for 1979 model appliances. These values indicate a slight reduction in water consumption over the 1975 and 1976 models tested in this laboratory.

3.2.2 Supply and Discharges Characteristics

Supply and discharge flow rates for seven different model dishwashers are presented in Table 7. It can be noted that maximum supply and discharge flow rates for these dishwashers, typically about 2.5 gallons per minute and 6 gallons per minute, respectively, are substantially less than for the clothes tested (Table 4).

4. EFFECTS OF VARIOUS PARAMETERS ON WATER CONSUMPTION

The effects of several parameters on appliance water consumption were evaluated based on laboratory testing and on review of existing studies. Parameters considered were those use conditions which vary with installation, and consumer usage patterns. These included supply pressure, cycle selection, and load size.

4.1 Clothes Washers

Several factors affect clothes washer water consumption. Primary factors include fill level and cycle selection. Supply pressure and temperature selection affect water consumption to a lesser degree.

4.1.1 Load Size/Water Level Setting

The larger the load size, the greater the volume of water required for the washing operation. As a rough estimate, every pound of clothes requires between 1.5 to 3.0 gallons of water for washing. Bonk [4] reports that small 10-12 pound capacity machines use 23 to 39 gallons, medium 14 pound capacity machines use 16* to 49 gallons and large 18 pound capacity machines use 27 to 54 gallons. Measurements of total clothes washer water consumption, Tables 2 and 3, are in good agreement with these estimates. For a given capacity machine, the large range of water consumption values reflects the variation in per cycle water consumption at the minimum and maximum fill level settings present on most machines.

4.1.2 Cycle Selection

Different garments and fabrics may require special care in washing. Thus, several wash cycles are provided on most machines. Common cycles include:

- o normal cycle
- o permanent press cycle
- o delicate cycle
- o soak cycle

A breakdown of usage for each of these cycles is not currently available, but a survey of washer owners conducted between 1968 and 1970 indicates that the normal cycle is used 89 percent of the time while the permanent press gentle, and other cycles account for 11 percent of all usage [5]. With the increased availability of synthetic and synthetic-natural fiber fabrics in recent years, current usage of the normal cycle may be expected to be somewhat reduced.

*The value of 16 gallons is for front-loading machines. Conventional top-loading machines would have a lower limit of about 25 gallons.

Water consumption differs substantially among cycles due to the wide range of appliance designs. As shown in Table 3, water consumption for some machines may be as much as 18 gallons higher on the permanent press cycle setting than on the normal cycle. Water usage on other cycles has not been investigated.

4.1.3 Supply Pressure

Fill volume for the wash and deep rinse subcycles is, in most models, controlled by a diaphragm-type pressure switch located between the inner and outer tubs (see Figure 1). This switch senses the depth of water in the tub, hence, the volume of the fill is independent of supply pressure. The spray rinse subcycle is usually timed, however, so the actual volume used in this subcycle is somewhat dependent on supply pressure. As was shown in Table 2, the spray rinse contribution to total water consumption is small. Pressure effects on this contribution are even smaller; typically an increase of 15 psi in the pressure, increases total consumption by about 1 gallon.

4.1.4 Temperature Selection

In general, hot and cold water which is supplied to automatic clothes washers enters a dual gate solenoid valve within the machine (see Figure 1). This valve controls the water flow and provides cold, warm, or hot water for the various subcycles. Cold water is obtained by actuating the cold water side of the valve, hot water by actuating the hot water side, and warm water by actuating both sides simultaneously. Mixing ratios for 50/50 hot/cold water are commonly used for warm water, but 60/40 and 40/60 ratios are also used in some machines.

Temperature selection does not affect water usage for the fill and deep rinse subcycles because, as previously mentioned, water consumption for these subcycles depends only on the the water level control setting and therefore the depth of water in the tub. However, temperature selection does affect water consumption on the spray rinse subcycles, which are timed. This is because the supply flow rate is higher for warm water spray rinses (both sides of the solenoid valve open) than for cold or hot water rinses (one side of the solenoid valve open). Although water usage is higher for warm spray rinse cycles, the difference is minimal -- typically about 1 gallon per cycle.

In summary, fill level influences clothes washer water consumption most strongly, followed by cycle selection. Both supply pressure and temperature selection affect only the water consumption of the spray rinse subcycle and are relatively unimportant.

4.2 Dishwashers

Several factors affect dishwasher water consumption; these include cycle selection and supply pressure.

4.2.1 Cycle Selection

Most dishwashers are equipped with a variety of wash cycles and special features. Typical wash cycles include:

- o super wash
- o normal wash
- o short wash
- o rinse/hold

Some manufacturers' estimates of water consumption on these cycles are presented in Table 6 for 1979 appliance models. Inspection of the estimates reveals that water savings of about 2 to 5 gallons per cycle are possible by using either the short wash cycle more frequently or the super wash cycle less frequently. Adequate washing performance on the water-conserving cycles is necessary however, in order for these savings to be realized.

4.2.2 Supply Pressure

As shown in Figure 2, static water supply pressure in the United States ranges between 20 and 130 psig. Residential plumbing system designs and water usage patterns add to the variation, and affect the pressure at which water is delivered to points of use within the home. The net result is a wide range of supply pressures under which appliances must satisfactorily operate.

The fill cycles for all current dishwashers are timed events. Supply pressure, which affects incoming water flow rates, therefore plays an important part in determining total dishwasher water consumption. Higher water supply pressures generally result in greater incoming water flow rates and thus greater dishwasher water consumption (the fill time remains constant and the water fills to a higher level in the sump). The supply pressure versus water consumption profile shown in Figure 3-Case 1 illustrates this fact. For this machine, which is equipped with a fixed-orifice fill valve, water consumption is 2 gallons per cycle greater at 60 psig supply pressure than at 20 psig. If the machine is designed to give satisfactory performance using the quantity of water consumed at a supply pressure of 20 psig, this additional 2 gallons is unnecessary.

Pressure-compensating fill valves are commonly used to reduce excessive water use and to provide a more uniform incoming water flow rate over the wide range of pressures encountered in the field. These valves utilize a flexible, variable-orifice flow disc similar to that used in low-flow faucets and showerheads. Inspection of the water consumption versus supply pressure profile for a machine equipped with the pressure-compensating disc, Figure 3-Case 2, illustrates the effectiveness of these devices. The water consumption of the machine varied by less than 1 gallon per cycle over the entire pressure range.

It should be noted here that while the water consumption of machines not equipped with pressure-compensating devices is reduced by decreasing water supply pressure, the same may not always be true for machines equipped with the devices. The tendency towards greater water consumption at low supply pressures shown in Figure 3-Case 2, precludes any general statements regarding pressure reduction as a means of saving water.

In summary, dishwasher water consumption can be reduced by about 2 to 5 gallons per cycle by using the normal and short wash cycles instead of the super and normal cycles respectively. Smaller water savings -- about 1 to 2 gallons

per cycle — are possible for machines not equipped with pressure-compensating flow discs, by reducing the supply pressure.

5. OPTIONS AND DESIGN MODIFICATIONS FOR APPLIANCE WATER CONSERVATION

Several options and design modifications to decrease appliance water consumption are possible. For clothes washers these involve using front-loading type machines, reusing wash water for clothes washing, and reducing the volume of water which is not actually needed for washing. For dishwashers they involve reducing the number of water changes or fills in a cycle and reducing the volume of water use per fill. Additional machine modifications, such as increased wash or rinse cycle time, may be required simultaneously to insure that performance is not degraded by the water-conserving changes.

Of the design modifications discussed herein, many have been implemented on various appliance models; others are still in the development stages in industry or have not yet become commercially available. For the latter case, water savings equivalent to those offered by the modification, for example, automatic water level control, are usually attainable by merely altering appliance usage habits.

5.1 Water Conservation Options for Clothes Washers

5.1.1 Front Loading Machines

The most commonly suggested and perhaps the most effective means of reducing water consumption for clothes washing is through use of commercially available front-loading type washers. Compared to conventional top-loading machines, front loaders require 30 to 50 percent less water (about 20 gallons) and 50 percent less detergent to wash equivalent loads (see Tables 2 and 3). Front loading machines are more expensive, however, and have a load capacity about 30 percent less than top-loaders. (Full-size top-loading machines range in capacity from 14 to 18 pounds of clothing. The front-loader capacity is rated at 14 pounds, but would more realistically wash about 12 pounds of clothes). The smaller load capacity of the front loader is not a significant disadvantage because, as data in Table 8 indicates, loads exceeding the capacity of the front-loader are seldom washed.

5.1.2 Suds-Saver Devices

Use of suds-saver devices for top-loading machines is a second means of reducing water consumption. The suds-saver feature, available as an option from several manufacturers, permits the reuse of wash water for subsequent wash loads. No water savings are obtained on the initial cycle with the suds-saver, but savings of about 20 gallons per cycle are generally realized on subsequent wash cycles for which the suds-saver is utilized. No substantial performance penalties are incurred with the suds-saver [6] but laundry practices, such as the order in which clothes are washed, must frequently be modified to accommodate the use of suds-saver.

Sales of sud-saver equipped clothes washers have decreased consistently over past years. Reasons cited for this sales decline include (1) elimination

of laundry tubs (required for storing wash water) in many newer homes (2) increased connections to public sewer systems (eliminating septic tank problems which the suds-saver reduced) and (3) public disfavor over washing clothes in "dirty" water. Sales of suds-savers is still strong in many areas of the country however, particularly where sewer connections are not available. A consumer education program emphasizing water, energy, and detergent savings is perhaps a good first step towards reviving this water saving option.

5.1.3 Better Use of Existing Water Level Controls

Most clothes washers currently in use are equipped with a water level selection control. Manual adjustment of the water fill level with this control to compensate for various load sizes and fabrics can result in minimum water usage. As indicated in Table 8, however, the control is generally not used to full advantage. Although typical dry wash loads weigh about 5.4 pounds capacity washers and 5.9 pounds for 18 pounds capacity machines, the maximum fill level setting is selected by consumers 79 and 60 percent of the time, respectively [5]. This anomaly is perhaps due in part to the user's concept of a full load, and to poor laundering habits—setting the control to maximum fill and leaving it there.

Inspection of Table 2 or 3 indicates that water savings with the level selection control would be as high as 25 gallons per cycle for cases in which the maximum fill setting is used when the minimum setting would suffice. Also, use of the level selection control eliminates the need to defer washing until a "full" load is available, as "partial" loads may be washed with the minimum amount of water necessary by adjusting the fill level.

5.2 Water Conservation Design Modifications for Clothes Washers

Water savings in addition to those offered by the front-loader and suds-saver are possible by reducing the volume of water used to the minimum which is actually needed for satisfactory performance. Several design modifications have been suggested as a means to this end [7,8]. Some of these include:

- o reducing tub volume
- o reducing clearance between inner and outer tubs
- o developing automatic water level control

A discussion of the rationale and expected water savings for each of these modifications follows.

5.2.1 Reduce Tub Volume

Clothes washer tub-volume has increased gradually over recent years (see Table 9). Data presented in Table 8 indicate that the additional capacity is utilized for less than 2 percent of all wash loads. If fill level controls are not adjusted frequently and accurately by the consumer, it would appear that a reduction in tub volume to 1972 sizes would result in water savings of about 4 gallons per cycle -- without much of a loss in utility. It should be pointed out however, that these savings will not be fully realized if the number of wash

cycles needed to launder the same amount of clothing increases proportionally with the smaller machine.

5.2.2 Reduce Clearance Between Inner and Outer Tubs

The clearance and hence enclosed volume between the inner and outer tubs of some top-loading machines is much greater than on others. This enclosed volume, while tending to dilute the concentration of suspended soil, is not involved directly in the washing process. Its reduction, if performance requirements can still be satisfied, can result in water savings. Clothes washers with reduced clearances of about 0.5 inch are already commercially available. As shown in Table 10, reducing the clearances of other machines to 0.5 inch offer water savings of as much as 2 gallons per cycle.

5.2.3 Develop Automatic Water Level Control

A device which could achieve substantial water savings is an automatic water level control. This device would respond to the amount and type of fabrics loaded into the machine, and would adjust the water level to the minimum required for proper laundering. By eliminating the need for user judgement, the automatic water level control would offer water savings equivalent to those obtained through optimum use of the current, manual water level control. The automatic water level control has been in development by manufacturers for several years, but has not yet reached a marketable stage [3].

5.3 Water Conservation Options and Design Modifications for Dishwashers

Water conservation changes for dishwashers basically involve reductions in the number of water changes in the wash cycle or reductions in the quantity of water used per water change.

5.3.1 Reduce the Number of Water Changes

The number and phasing of dishwasher subcycles or water changes differs among various appliance models, as does the total water consumption and washing performance. As shown in Table 5, with the exception of a slight trend towards higher washing indices at greater water consumption levels, there appears to be little correlation between any of the aforementioned parameters. It can also be noted from Table 5, that the washing index of some models is substantially greater than others; a range of 66 percent to 92 percent was measured.

Elimination of the first wash and rinse subcycles for lightly soiled dishes, or the final rinse for most wash loads has been suggested as a means of reducing water and energy consumption [7,8]. Based on the test results of Table 5, these changes appear feasible for well-designed machines. Adequate performance on the shorter cycles will of course, be dependent on the extent of soil, and dishwasher design. Several manufacturers currently offer machines with such short cycle options. Consumer use of these cycles can result in water savings of about 2 to 5 gallons per cycle.

5.3.2 Reduce the Quantity of Water Used Per Water Change

The quantity of water used per water change or fill can be reduced in three ways: (1) reducing water supply pressure (keeping fill time constant), (2) improving the fill level control, and (3) changing the geometry of the washing chamber.

As was discussed in Section 4.2.2, for machines not equipped with a pressure-compensating fill valve, a reduction in water supply pressure results in a reduction in fill rate and water savings of about 1 gallon per cycle for pressure reductions of about 20 psi. Pressure reductions will be limited to the point at which the water level in the sump falls below the level of the immersion heater or circulating pump inlet during the cycle.

Provided the dishwasher circulating pump and immersion heater is kept supplied with water, the effect of fill volume reduction will be confined to a slight increase in the soil concentration of the wash water. The relation between soil concentration and washing performance has not been investigated, but should be determined if this modification is to be recommended.

An alternative to supply pressure reduction is the use of a pressure-independent filling arrangement such as that used on clothes washers (see Section 4.1.3). Water savings with such a system would also be about 1 gallon per cycle.

The third means of reducing water consumption involves altering the geometry of the dishwasher sump region so that a smaller volume of water is required to keep the circulating pump primed. This typically involves increasing the slope of the washing chamber floor toward the pump water inlet, and recessing the pump water inlet. This modification, which offers water savings of about 1 to 2 gallons per cycle, has already been incorporated by several manufacturers.

6. SUMMARY AND CONCLUSIONS

Total water consumption for a typical top-loading clothes washer is about 50 gallons for a normal cycle at maximum fill level -- 23 gallons each for the wash and deep rinse subcycles and 3 gallons for the spray rinse. Water consumption is strongly dependent on fill level and cycle selection, but is only slightly influenced by water supply pressure or temperature selection. Supply and discharge rates are generally about 4 to 9 gallons per minute and 9 to 16 gallons per minute respectively.

Clothes washer water consumption may be reduced by several means. A summary of various water conservation options and design modifications are given in Table 11, along with estimated water savings for each. It should be noted that the most significant of these options -- front-loading machines and suds-saver devices -- are already commercially available. Others, such as automatic water level control, can be duplicated by the consumer developing better laundering practices.

For a large percentage of the dishwashers in use, average water consumption is about 14 to 15 gallons for a normal cycle, which generally consists of from 5 to 7 wash and rinse subcycles. Newer models have reduced this average to about 12 to 13 gallons. Water consumption is about 2 to 5 gallons lower on short cycle settings and about 2 gallons higher on super-wash cycles as compared to normal cycles. Supply and discharge rates for the seven models tested ranged from about 1 to 2.5 gallons per minute and from 5 to 6 gallons per minute respectively.

A summary of water conservation design options for dishwashers is presented in Table 12 along with estimated water savings. Again, it should be noted that the most effective water saving option -- reduced number of water changes -- is possible with some machines currently on the market. Consumer use of the shorter cycles is essential in saving water.

7. REFERENCES

1. Palla, R. L., "The Potential for Energy Savings with Water Conservation Devices", NBSIR 79-1770, National Bureau of Standards, Washington, D. C., July 1979.

2. Muller, J. G., "The Potential for Energy Savings Through Reductions Through the Use of Flow Reducing Devices and Other Conservation Methods", in Water Conservation With Water Saving Devices, T. B. Shelton, ed., Proceedings of a Conference, Rutgers University, New Brunswick, New Jersey, November 30, 1976.

3. Personal Communication with Raymond M. Goodman, Whirlpool Corporation.

4. Bonk, M. J., "Water Consumption of Automatic Dishwashers and Water Consumption of Automatic Clothes Washers," Cabin John Water-Saving Test Program, Washington Suburban Sanitary Commission, Hyattsville, Maryland, 1973.

5. "Laundry practices of normal and large capacity automatic washer owners," The Proctor and Gamble Company, 1970.

6. Goodman, R. M., "Reduced Energy Consumption of Automatic Washers - Benefits and Penalties," Proceedings of the Conference on Major Home Appliance Technology for Energy Conservation, Purdue University, West Lafayette, Indiana, February 27 - March 1, 1978.

7. Booz, Allen, and Hamilton, Inc. "Development of Appliance Energy Efficiency Targets and Consumer Costs," report prepared for The Federal Energy Administration under contract no. CR-04-60487-00, June 1976.

8. Science Applications, Inc. "Energy Efficiency Program for Clothes Washers, Clothes Dryers, and Dishwashers," report prepared for the Department of Energy under contract no. CR-04-60706-00, November 1977.

9. Consumer Union, "Washing Machines," Consumer Reports, Mt. Vernon, New York, October 1978, and similar articles in 1977, 1975, 1974, 1973, and 1972.

10. California Department of Water Resources, Water Conservation Information Bulletin, February 1977.

11. Washington Suburban Sanitary Commission, "Fixture List," Hyattsville, Maryland, January 1975.

12. General Electric Field Survey Data, 1970.

13. Davies, A. D., et al., "Household Appliance Usage Data", NBSIR 80-1994, National Bureau of Standards, Washington, D.C., February 1980.

Table 1 - Typical Wash/Rinse Phasing For Clothes Washers [7]

Regular cycle

- Suds return (if machine is so equipped)
- Fill
- Wash (time variable to over 15 minutes)
- Spin and drain (to suds saver, if so equipped)
- Spray rinse and spin
- Spin and drain
- Fill for rinse
- Stop

Permanent press cycle

- Fill for wash
- Wash
- Spin and partial drain
- Fill for cool rinse
- Spin and partial drain
- Fill for cool rinse
- Agitate
- Spin and drain
- Fill for rinse
- Agitate
- Spin and drain

Soak cycle

- Fill for soak
- Agitate
- Soak (approximately 4 minutes)
- Spin and drain
- Stop
- Fill for regular cycle

Table 2 - Clothes Washer Water Consumption Breakdown for Various Fill Levels

Test Unit	Fill Level	Subcycle Water Consumption*, gallons			Total Water Consumption*
		Wash	Spray Rinse	Deep Rinse	
CW1	Max	24.9	4.9	25.5	55.3
	Min	10.7	5.3	11.0	27.0
CW3	Max	26.0	2.2	26.1	54.3
	Min	8.2	2.3	8.2	18.7
CW4	Max	19.2	3.3	19.5	42.0
	Min	10.2	3.5	10.5	24.2
CW8	Max	26.1	2.9	26.3	55.3
	Min	13.0	3.0	12.9	28.9
CW10**	Max	8.6	3.6	14.9	27.1
	Min	5.6	3.5	9.8	18.9
CW11	Max	23.8	8.1	24.3	56.2
	Min	9.4	8.1	9.6	27.1

*Normal cycle setting, warm wash/cold rinse temperature setting, supply pressure = 35 psig flowing

**Front loading machine -- 7 lb standard test load used at maximum fill level, 3 lb load used at minimum

Table 3 - Some Reported Values for Clothes Washer Water Consumption

Reference	Consumer Reports [9]*	DWR[10]**	WSSC [11]**
Manufacturer and Model	-----Water Consumption per Cycle, gallons ---		
	Cycle Setting	Fill Level, Normal Cycle	
	Normal (Perm-Press)	Min-Max	Min-Max
Manufacturer 1			
14 lb	--	20-43	27-49
18 lb	51 (47)	23-47	27-53
Manufacturer 2			
14 lb	--	16-43	26-36
18 lb	47 (50)	16-47	27-53
Manufacturer 3			
Large Capacity	41 (52)	20-40	20-40
Manufacturer 4			
Top Loader	53 (53)	33-51	49(max)
Front Loader	--	20-31	33(max)
Manufacturer 5			
18 lb	51 (69)	27-53	--

*Normal Cycle, maximum fill level, 40 psig supply pressure, 8 lb load. Numbers in parenthesis indicate water consumption on permanent press cycle.

**Normal Cycle, minimum-maximum fill level.

Table 4 - Clothes Washer Supply and Discharge Flow Rates

Test Unit	Flow Rate, GPM	
	Supply*	Discharge
CW1	4.9	10.3
CW3	4.2	14.3
CW4	3.8	16.1
CW8	8.7	9.1
CW10	5.6	15.2

*Warm temperature setting, supply pressure = 35 psig flowing

Table 5 - Dishwasher Cycle Phasing, Water Consumption, and Washing Index

Test Unit	Water Consumption*, gallons Subcycle**							Total	Washing Index***
DW1			R 2.6	W 3.1	R 3.1	R 3.1	R 3.3	15.2	75%
DW2		W 2.4	R 2.0	W 2.0	R 2.1	R 2.1		10.6	66
DW3	R 2.1	W 2.2	R 2.7	W 2.2	R 2.2	R 2.3		13.7	91
DW6		W 2.2	R 2.2	W 2.2	R 2.2	R 2.2	R 2.2	13.2	87
DW7	W 2.7	R 1.8	R 1.8	W 2.7	R 2.7	R 1.8	R 2.7	16.2	70
DW8		W 2.4	R 2.7	W 2.7	R 2.7	R 2.7	R 1.5	14.7	92
DW10		W 2.4	R 2.4	R 2.4	W 2.4	R 2.4	R 2.4	14.4	88

*Supply pressure = 35 psig flowing
**W = Wash, R = Rinse
***Measured in accordance with ANSI A 197.5 (AHAM DW-1)

Table 6 - Manufacturers' Estimates of Dishwasher Water Consumption at Various Cycle Settings

Manufacturer and Model*	Water Consumption Per Cycle, gallons			
	Super Wash	Normal Wash	Short Wash	Rinse & Hold
A1	14.3	-	10.2	4.2
A2	13.5	10.3	9.0	3.9
B1	15.0	13.5	7.5	2.3
B2	15.2	12.9	8.4	2.2
C1	16.5	13.8	8.3	2.8
D1	13.9	-	9.3	4.6
E1	13.8	9.2	-	2.3

*1979 Models

Table 7 - Dishwasher Supply and Discharge Flow Rates

Test Unit	Flow Rate, GPM	
	Supply*	Discharge
DW1	1.3	4.0
DW2	1.4	5.0
DW3	2.5	6.1
DW6	2.5	6.0
DW7	1.7	5.1
DW8	1.4	4.1
DW10	1.2	4.6

*Supply pressure = 35 psig flowing

Table 8 - Typical Weights of Clothes Loads Washed [5]

Load Size	Normal Capacity	Large Capacity
Over 12 Pounds	1%	2%
Over 10 Pounds	3	5
Over 8 Pounds	7	14
Over 6 Pounds	34	45
Over 4 Pounds	59	48
Over 2 Pounds	93	93
Less Than 2 Pounds	7	7
All Loads		
Average	5.4 Pounds	5.9 Pounds
Median	5.0 Pounds	5.5 Pounds

Table 9 - Increase in Clothes Washer Tub Volume Over Recent Years [9]

	Gallons of Water Required for Single Fill*					
	Model Year					
	1972	1973	1974	1975	1977	1978
Number of Washer Tested	12	16	14	15	14	14
Greatest Volume	27	25	25	26	25	26
Average Volume	20.3	22.0	22.4	23.3	22.9	23.1
Smallest Volume	12	15	16	19	19	10

*Two fills are used in most wash cycles

Table 10 - Water Savings Attainable at Maximum Fill Levels by Reducing Inner-To-Outer Tub Clearance to 0.5 Inches

Test Unit	Average Clearance (in)	Inner Tub Dimensions, in		Enclosed Volume, in^3		Water Saved Per Cycle, gallons
		Inside Diameter	Height to Max Fill	Original Clearance	0.5 Inch Clearance	
CW1	1.13	20.3	12.0	445	193	2.2
CW3	0.85	20.8	13.3	373	219	1.4
CW4	0.60	21.0	12.3	248	204	0.4
CW8	0.78	21.3	13.5	357	228	1.2
CW11	0.88	19.8	12.5	349	196	1.4

Table 11 - Water Conservation Design Options and Estimated Water Savings for Clothes Washers

Design Option	Estimated Water Savings Per Cycle	
	Gallons	Percent*
Front Loader Design**	20	40
Suds-Saver***	10	20
Reduced Tub Volume**	4	8
Reduced Clearance Between Inner & Outer Tubs**	2	5
Automatic Water Level Control	25	50

*Water Consumption of Typical Wash Cycle Taken to be 50 Gallons
**Incorporated on Some Machines
***Based on One Reuse of Wash Water (Savings Shown are an Average for the Regular and the Reuse Cycle)

Table 12 - Water Conservation Design Options and Estimated Water Savings for Dishwashers

Design Option	Estimated Water Savings Per Cycle	
	Gallons	Percent*
Reduce Number of Water Changes		
Eliminate First Wash and Rinse** (Short Cycle)	5	33
Eliminate Final Rinse**	2.5	16
Reduce Quantity of Water Per Fill		
Develop a More Accurate Fill Control	1	5
Change Geometry of** Washing Chamber	1.5	10

*Water Consumption of Standard Dishwasher Taken to be 15 Gal/Cycle

**Incorporated on Some Machines

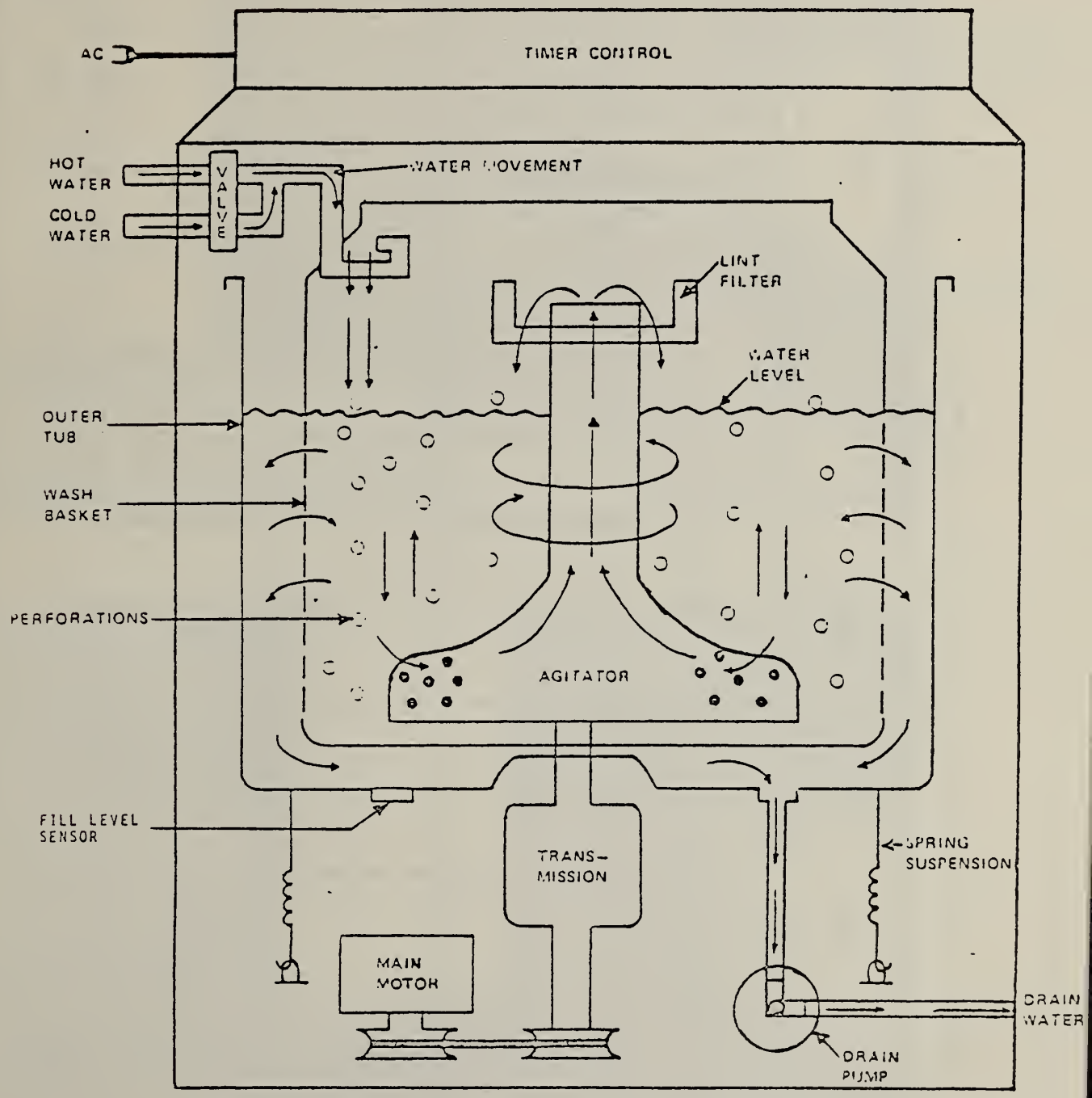


Figure 1 - Schematic of a Typical Top-Loading Clothes Washer [8]

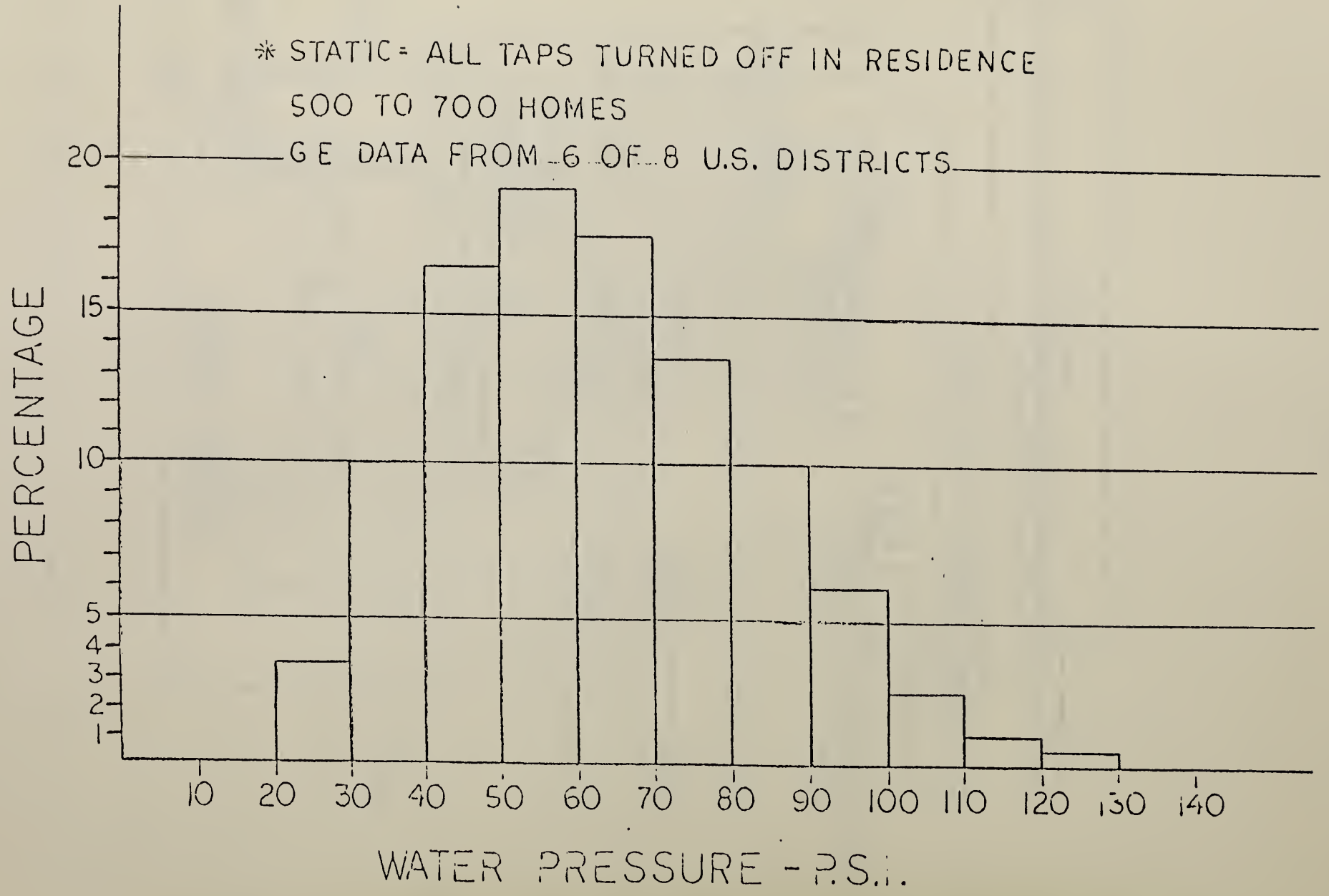
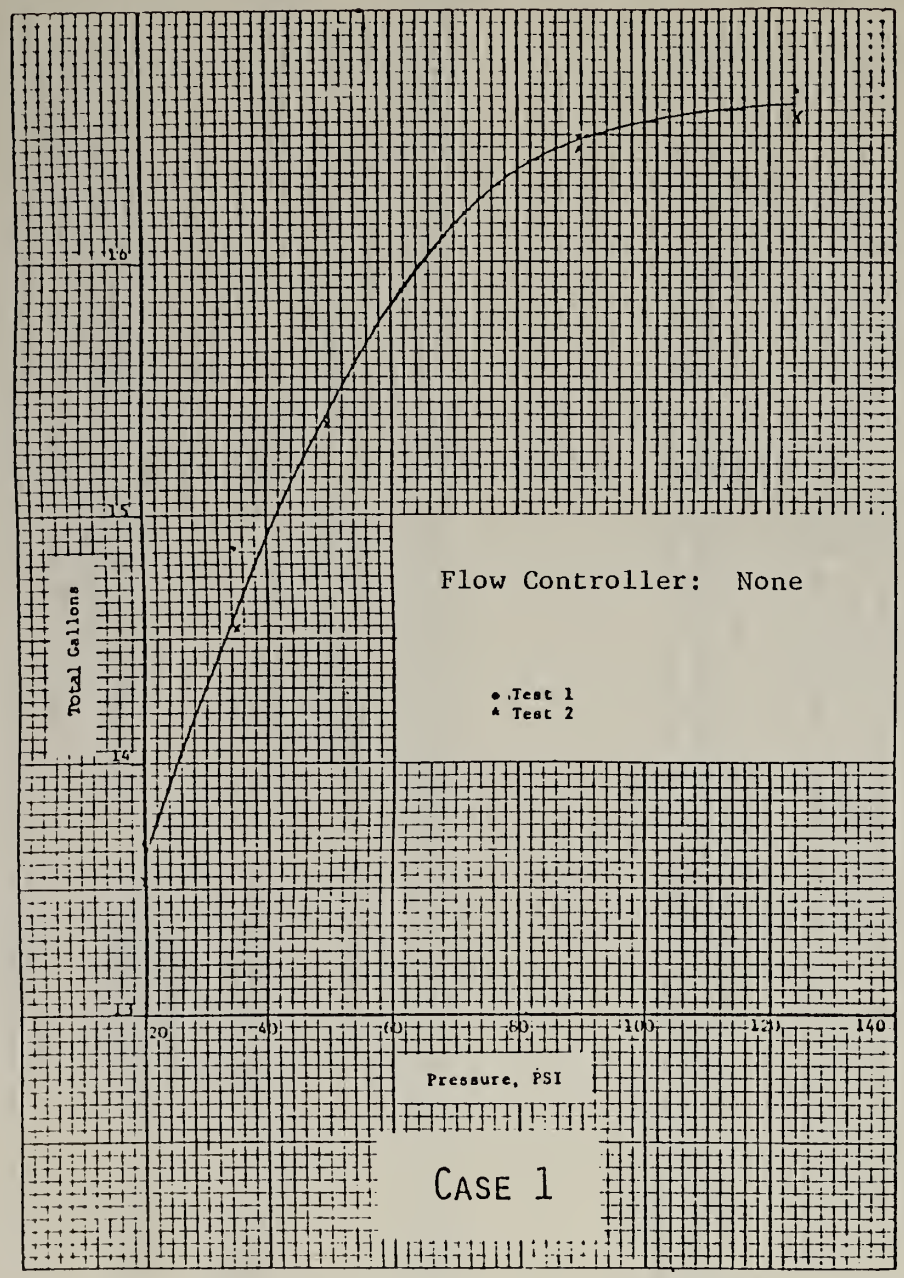


Figure 2 - Distribution of Static Water Pressure Found in Survey of Residences Throughout U.S. [12]



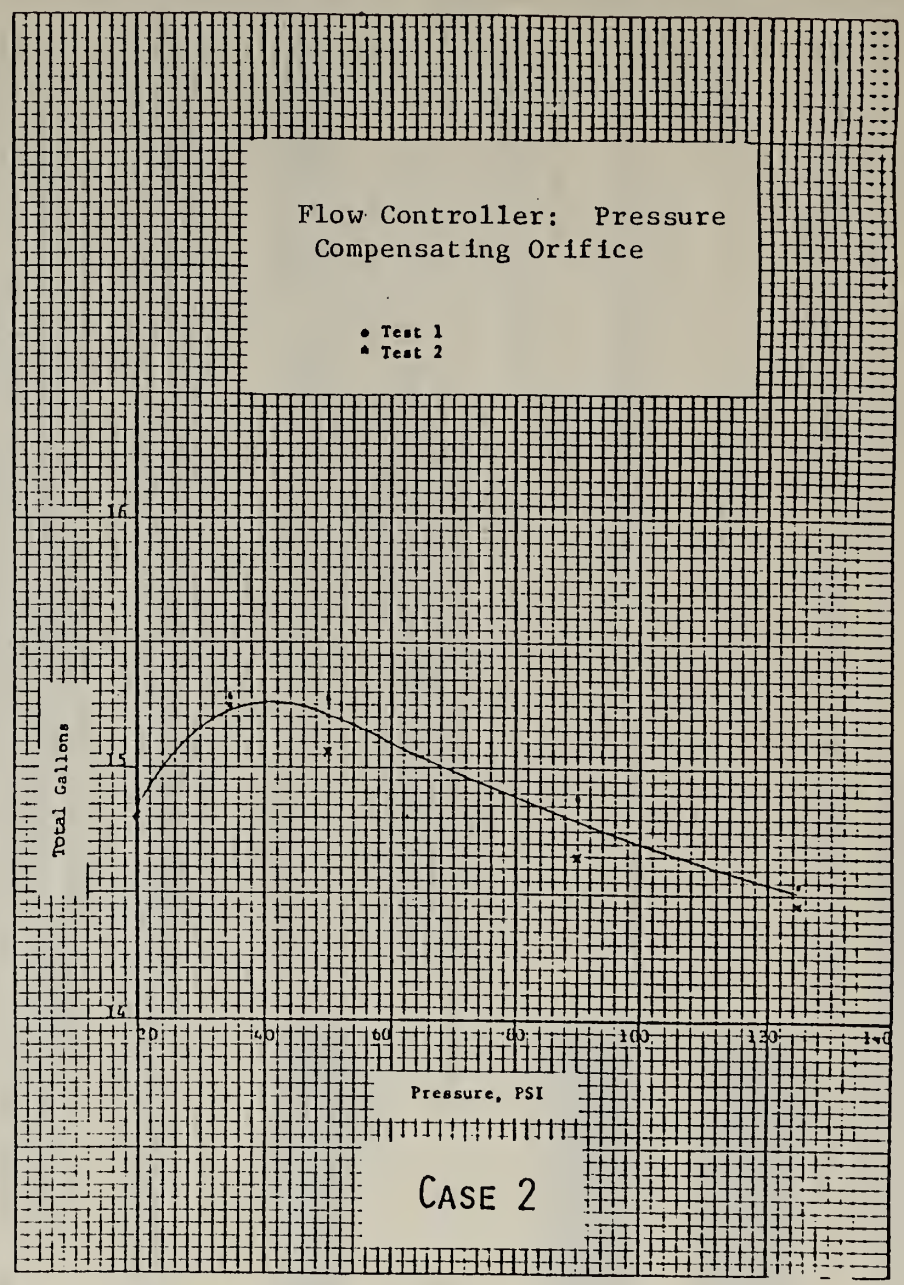


Figure 3 - Effect of Water Supply Pressure on Dishwasher Water Consumption

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☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

A study has been undertaken to quantify appliance water consumption and the effectiveness of various consumer usage techniques and manufacturer design modifications for saving water. Appliances considered are clothes washers and dishwashers. Through a comparison of estimated water savings, the study indicates that the most significant means of saving water are those which are already commercially available -- front-loading machines and suds-saver options for clothes washers, and short-cycle settings for dishwashers. Water savings of about 20 to 30 percent estimated with these features or about 10 gallons for clothes washers and 3 gallons for dishwashers.

Several appliance design modifications are also evaluated but do not offer the same level of savings. Water usage characteristics such as supply and discharge flow rates and the effect of supply pressure and cycle selection are presented.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Appliances; clothes washer; discharge; dishwasher; residential; supply; water conservation; water consumption.

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